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Original Study

Oral Health, Disability and Physical Function: Results From Studies of Older People in the United Kingdom and United States of America

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A B S T R A C T

Objectives: Studies examining the associations between oral health and disability have limited oral health measures. We investigated the association of a range of objectively and subjectively assessed oral health markers with disability and physical function in older age.

Design, Setting, and Participants: Cross-sectional analyses were based on the British Regional Heart Study (BRHS) comprising men aged 71 to 92 years (n = 2147) from 24 British towns, and the Health, Aging, and Body Composition (HABC) Study comprising men and women aged 71 to 80 years (n = 3075) from the United States. Assessments included oral health (periodontal disease, tooth count, dry mouth, and self-rated oral health), disability, and physical function (grip strength, gait speed, and chair stand test).

Results: In the BRHS, dry mouth, tooth loss, and cumulative oral health problems (≥3 problems) were associated with mobility limitations and problems with activities of daily living and instrumental activities of daily living; these remained significant after adjustment for confounding variables (for ≥3 dry mouth symptoms, odds ratio (OR) 2.68, 95% confidence interval (CI) 1.94–3.69; OR 1.76, 95% CI 1.15–2.69; OR 2.90, 95% CI 2.01, 4.18, respectively). Similar results were observed in the HABC Study. Dry mouth was associated with the slowest gait speed in the BRHS, and the weakest grip strength in the HABC Study (OR 1.75, 95% CI 1.22, 2.50; OR 2.43, 95% CI 1.47–4.01, respectively).

Conclusions and Implications: Markers of poor oral health, particularly dry mouth, poor self-rated oral health, and the presence of more than 1 oral health problem, were associated with disability and poor physical function in older populations. Prospective investigations of these associations and underlying pathways are needed.

Disability and poor physical function are common in older age and are associated with poor quality of life, mortality, and hospitalization.[1–3] In addition, oral health problems (periodontal disease, tooth loss, and dry mouth) are very prevalent in older people and can affect chronic diseases and mortality, and adversely influence nutritional intake.[4–7]

Furthermore, poor oral health in older age is associated with disability and declining physical function.[8–12] Tooth loss was linked to problems with instrumental activities of daily living (IADL)[13] and activities of daily living (ADL),[10,13–15] developing mobility limitations,[14] and decline in physical performance.[12,16,17] Moreover, periodontal

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disease was associated with IADL problems,[13] whereas poor self-rated oral health was linked to ADL problems.[15] Oral health markers are also associated with physical function. Periodontal disease was associated with a decline in handgrip strength,[18] whereas having no natural teeth (edentulism) was associated with a decline in gait speed.[11] In another study, the association between tooth loss and gait speed was attenuated when adjusted for inflammation.[19]

Although existing evidence suggests an association between oral health problems and disability and physical function in older age, studies so far have limited oral health measures (mainly periodontal disease and tooth loss). Therefore, the aim of this cross-sectional study is to examine the association of objectively and subjectively assessed measures of oral health with disability and physical function in 2 studies of community-dwelling older adults in the United Kingdom (UK) and United States (US).

Methods

The British Regional Heart Study

The British Regional Heart Study (BRHS) is a prospective cohort study in which 7735 men aged 49 to 50 years were recruited in 1978–1980 from 24 towns across the UK.[20] When participants were aged 71 to 92 years, they were invited to a 30-year re-examination in 2010–2012.[20] A total of 2147 participants (68% response rate) completed the postal questionnaire and 1722 participated in the physical examination (55% response rate).[20] In 2010–2012, information from questionnaires and physical and oral examination was available.[21] Ethical approval was provided by the relevant ethical committees. Informed written consent was obtained from study persons to participate in the investigations, which were conducted in accordance with the Declaration of Helsinki.

The Health, Aging, and Body Composition Study

The Health, Aging, and Body Composition (HABC) Study is a prospective cohort study in which 3075 white and African-American men and women, aged 70–79 years, were recruited. White participants were randomly selected through Medicare, whereas African Americans were selected from neighborhoods with a zip code around Memphis and Pittsburgh.[22] Only individuals who were able to walk 0.25 miles or climb 10 steps without any difficulty were included in the study at baseline. In year 2 (1998–1999), participants aged 71–80 years (n = 1975) underwent an oral health and physical assessment and completed questionnaires. All of the participants provided written informed consent. Ethical approval was provided by several institutional review boards.[22]

Oral Health

In both studies an oral examination comprised objective measures, including a count of natural teeth, and periodontal disease measures (loss of attachment and pocket depth). Details of these measurements can be found elsewhere.[21,23] Subjective measures were assessed through questionnaires and consisted of self-rated oral health; dry mouth; difficulty eating due to mouth, teeth or dentures problems; sensitivity to hot, cold, or sweets; limit of food because of gum problems; and dental service use. In the BRHS, dry mouth was measured based on the Xerostomia Inventory Scale[24]; in the HABC Study, participants were asked if they had dry mouth symptoms when eating.

Number of natural teeth was categorized as 5-level category (≥21 teeth, 15–20, 8–14, 1–7 and 0); edentulism (no natural teeth, and ≥1); and having ≥21 and <21 remaining teeth.[25] Periodontal pocket depth was grouped for BRHS as >20% sites affected >3.5 mm, and for HABC Study as >20% sites affected ≥3 mm. Loss of attachment was grouped for BRHS as >20% sites affected >5.5 mm, and for HABC Study as >20% sites affected with ≥3 mm.[21,26] Self-rated oral health was categorized as excellent/good and fair/poor in both studies. In the BRHS, dry mouth was categorized into 0, 1 to 2 or ≥3 dry mouth symptoms. Dental service use consisted of regular check-up, occasional check-up, only when having trouble, and never go to the dentist in the BRHS, whereas the HABC Study included going to the dentist ≥2 times a year, once per year, and less than once per year. A cumulative measure of oral problems was created. In the BRHS, it was based on having ≥3 dry mouth symptoms, <21 natural teeth, any difficulty eating, and sensitivity to hot, cold, or sweets[27]; in the HABC Study, limit of food because of gum problems was utilized instead of sensitivity to hot, cold, or sweets. The cumulative oral health problem variable was then grouped as 0, 1, 2, and ≥3 problems. Details of both studies are summarized in Supplementary Figure 1 in the Appendix.

Disability

In the BRHS, information on disability was based on questionnaires in 2010–2012. Mobility limitations was based on difficulty going up or down stairs or walking 400 yards. Having problems with ADL was based on difficulty or needing help doing any of the following tasks: (1) getting in and out of a chair, (2) dressing and undressing yourself, (3) bathing or showering, (4) feeding yourself, including cutting food, or (5) getting to and using the toilet. IADL problems was based on any difficulty or needing help in shopping for personal items, preparing your own meals, using telephone by yourself, managing money, or using public transport. In the HABC Study, data from year 2 (1998–1999) questionnaires were used to ascertain disability. Mobility limitations was based on any difficulty in walking 1 quarter of a mile or climbing 1 flight. ADL problems included any problem or needing help in dressing, getting in and out of bed, or bathing on your own. Information on IADL was not available.

Physical Function

Physical function measures were obtained through physical examinations in both studies. In the BRHS, gait speed was assessed as the time (in seconds) required to walk 3 meters at normal pace.[28] Grip strength (Jamar Hydraulic Hand Dynamometer Model J00105; Sammons Preston Rolyan, Bollingbrook, IL) was measured 3 times for each hand and the highest reading was used.[20] Chair-stand test was assessed as time taken (in seconds) for participants to sit and stand from a chair 5 times. In the HABC Study, grip strength and gait speed were measured. Gait speed was measured as the time (seconds) taken to walk 400 m at a steady rate (long distance corridor walk).[29] Grip strength (isometric Jamar Hydraulic Hand Dynamometer) was measured twice for each hand, and the highest reading in either hand was used.[30]

Covariates

In both studies, information on socioeconomic position, smoking, physical activity, and history of doctor-diagnosed cardiovascular disease (CVD) and diabetes was obtained from questionnaires.[20,23] In the BRHS, socioeconomic position was based on occupational social class, which was derived from the longest-held occupation when participants entered the study.[21] Smoking history was based on combined set of questions from previous questionnaires, whereas physical activity was based on self-report of usual physical activity levels.[31] In the HABC Study, socioeconomic position was based on the highest level of education accomplished.[23] Physical activity was a composite measure of the total calories consumed per kilogram per week from a number of activities.[32] For both studies, measures of self-rated general health

and regular use of prescribed medications causing dry mouth (xerostomia) were included.[33]

Statistical Analysis

Because of differences in the populations of the BRHS and HABC Study and in the assessment of oral health measures and covariates, we conducted separate analyses for the 2 studies. Logistic regression was performed to calculate odds ratios (ORs) [95% confidence interval (CI)] for the associations of poor oral health with disability and poor physical function. For physical function outcome, measures included the slowest gait speed (top quintile), slowest chair-stand speed (top quintile), and weakest grip strength (bottom quintile). In the BRHS, fully adjusted models included age (continuous), social class (2 levels), smoking (4 levels), physical activity (5 levels), history of CVD, and diabetes. In the HABC Study, adjustment for age (continuous), sex, race, education (3 levels), smoking (3 levels), physical activity (continuous), and history of CVD and diabetes was performed. In both studies, we further adjusted the models for self-rated general health (continuous), and analyses with dry mouth were also adjusted for use of medications (3 levels). Covariates were tested for correlation before they were entered in the models. All analyses were performed using SAS v 9.4 software (SAS Institute, Inc, Cary, NC).

Results

The baseline characteristics and prevalence of oral health measures in the BRHS and HABC Study populations are presented in Table 1. The mean age of BRHS participants was 78.8 years, 48% were in manual social class, 20% were edentulous, 35% reported poor self-rated oral health, 62% had at least 1 dry mouth symptom, and 36% had ≥2 cumulative oral health problems. In the HABC Study, mean age was 74.7 years, 48% were male and 52% female, 58% white and 42% African American, and 42% completed postsecondary education. In addition, 11% had no natural teeth, 31% reported poor self-rated oral health, 4% had dry mouth, and 22% had at least 2 oral health problems.

Table 2 presents ORs and 95% CIs for the associations of objective and subjective markers of oral health with measures of disability in the BRHS. Tooth loss was associated with ADL (OR 1.65, 95% CI 1.05–2.57) after full adjustment for covariates (age, social class, smoking, physical activity, history of CVD, and diabetes). Edentulism was associated with IADL problems (OR 1.51, 95% CI 1.03–2.22). Fair/poor self-rated oral health was associated with mobility limitations and IADL problems (OR 1.44, 95% CI 1.12–1.85; OR 1.66, 95% CI 1.24–2.22, respectively). Similarly, having ≥3 dry mouth symptoms and ≥2 oral health problems was associated with mobility limitations, ADL problems, and IADL problems. Dental service use was associated with mobility limitations and IADL problems.

The associations between oral health and physical function are presented in Table 3. Periodontal pocket depth >3.5 mm was associated with having the weakest grip strength (OR 1.59, 95% CI 1.14–2.20). In addition, ≥3 dry mouth symptoms and limited dental service use were associated with the slowest gait speed (OR 1.75, 95% CI 1.22–2.50; OR 1.69, 95% CI 1.08–2.62, respectively).

Table 4 presents the associations between oral health markers and disability in the HABC Study. In the fully adjusted model, tooth loss was associated with mobility limitations and ADL problems. Associations with mobility limitations and ADL problems were observed in fully adjusted models for fair/poor self-rated oral health (OR 1.19, 95% CI 1.10–1.30; OR 1.27, 95% CI 1.15–1.41, respectively), dry mouth (OR 2.26, 95% CI 1.50–3.39; OR 2.23, 95% CI 1.46–3.41, respectively), and difficulty eating (OR 1.51, 95% CI 1.22–1.86; OR 1.90, 95% CI 1.50, 2.40). Presence of ≥3 oral health problems was associated with mobility limitations and ADL problems.

Table 1
Population Characteristics and Prevalence of Oral Health Problems in the BRHS and the HABC Study

	BRHS (n = 2147)
Age (y), mean ± standard deviation	78.8 ± 4.8
Social class, n (%)	
Nonmanual	1081 (52%)
Manual	1003 (48%)
Smoking, n (%)	
Never	768 (36%)
Long-term exsmoker (gave up before 1983)	1153 (54%)
Recent exsmoker	122 (6%)
Current smoker	91 (4%)
Physical activity, n (%)	
Inactive	405 (20%)
Occasional	475 (24%)
Light	447 (22%)
Moderate	278 (14%)
Moderate vigorous	232 (12%)
Vigorous	165 (8%)
History of cardiovascular disease, n (%)	500 (24%)
History of diabetes, n (%)	321 (16%)
Oral health measures	
Edentulism (no natural teeth)	338 (20%)
<21 teeth	1066 (64%)
>20 % sites with loss of attachment >3.5 mm	303 (24%)
>20% sites with pocket depth >5.5 mm	365 (29%)
Fair/poor self–rated oral health	719 (35%)
≥1 dry mouth symptoms	1272 (62%)
≥2 cumulative oral health problems	766 (36%)
Never been to the dentist	307 (15%)
Mobility limitations, n (%)	564 (27%)
ADL problems, n (%)	412 (20%)
IADL problems, n (%)	367 (17%)
	HABC Study (n = 3075)
Age (y), mean ± standard deviation	74.7 ± 2.9
Sex, n (%)	
Male	1491 (48%)
Female	1584 (52%)
Race, n (%)	
White	1794 (58%)
African American	1281 (42%)
Education, n (%)	
Less than high school	775 (26%)
High school graduate	1000 (33%)
Postsecondary	1292 (42%)
Smoking†, n (%)	
Never	1348 (44%)
Current smoker	318 (10%)
Former	1404 (46%)
Physical activity (kcal/kg/wk)*,†, mean ± standard deviation	82.9 ± 69.3
History of cardiovascular disease, n (%)	106 (4%)
History of diabetes, n (%)	142 (5%)
Oral health measures	
Edentulism (no natural teeth)	207 (11%)
<21 teeth	1031 (52.2%)
>20 % sites with loss of attachment ≥3 mm	721 (64%)
>20% sites with pocket depth ≥3 mm	627 (55%)
Poor self–rated oral health	829 (31%)
Dry mouth	107 (4%)
≥2 Cumulative oral health problems	617 (22%)
Visiting dentist less than once per year	993 (37%)
Mobility limitations, n (%)	882 (29%)
ADL problems, n (%)	467 (17%)

*Total kcal/kg/wk from household chores, walking and stairs, exercise or recreation activities and work or volunteering or caregiving.
†Baseline data (year 1).

Odds ratios for oral health markers and physical function in the HABC Study are presented in Table 5. Periodontal disease and tooth loss were not associated with grip strength and gait speed. Poor self-rated oral health was associated with the slowest gait speed (OR 1.16, 95% CI 1.03–1.30). Dry mouth was associated with the weakest grip

Table 2
ORs (95%CI) for The Association of Oral Health Markers With Mobility Limitations, ADL Problems, and IADL Problems in 2147 Older Men Age 71–92 Years in the BRHS

Oral Health Markers	Mobility Limitations (n = 564; 27%)			ADL Problems (n = 412; 20%)			IADL Problems (n = 367; 17%)		
	n (%)	Age-Adjusted	Fully- Adjusted*	n (%)	Age-Adjusted	Fully- Adjusted*	n (%)	Age-Adjusted	Fully- Adjusted*
Objective		OR (95% CI)	OR (95% CI)		OR (95% CI)	OR (95% CI)		OR (95% CI)	OR (95% CI)
Tooth loss									
≥21teeth	106 (18%)	1.00	1.00	70 (12%)	1.00	1.00	56 (10%)	1.00	1.00
15–20 teeth	68 (20%)	1.10 (0.78, 1.56)	0.93 (0.62, 1.38)	44 (13%)	1.07 (0.71, 1.60)	0.97 (0.62, 1.53)	45 (14%)	1.40 (0.92, 2.14)	**1.31 (1.12, 2.95)**
8–14 teeth	79 (30%)	**1.85 (1.31, 2.60)**	1.48 (0.98, 2.22)	57 (22%)	**1.90 (1.29, 2.81)**	**1.65 (1.05, 2.57)**	44 (17%)	**1.75 (1.13, 2.69)**	1.54 (0.92, 2.58)
1–7 teeth	38 (32%)	**1.90 (1.22, 2.98)**	1.23 (0.73, 2.07)	22 (18%)	1.39 (0.81, 2.36)	1.02 (0.56, 1.86)	20 (17%)	1.54 (0.88, 2.70)	1.00 (0.51, 1.95)
0 teeth	103 (31%)	**1.73 (1.26, 2.39)**	1.14 (0.76, 1.69)	76 (23%)	**1.80 (1.24, 2.60)**	1.28 (0.82, 1.99)	74 (22%)	**2.16 (1.46, 3.19)**	**1.82 (1.12, 2.95)**
Edentulism									
≥1 teeth	291 (22%)	1.00	1.00	193 (15%)	1.00	1.00	165 (13%)	1.00	1.00
0 teeth	103 (31%)	**1.36 (1.04, 1.79)**	1.01 (0.72, 1.42)	76 (23%)	**1.45 (1.07, 1.98)**	1.12 (0.78, 1.62)	74 (22%)	**1.65 (1.20, 2.26)**	**1.51 (1.03, 2.22)**
Tooth loss									
≥21teeth	106 (18%)	1.00	1.00	70 (12%)	1.00	1.00	56 (10%)	1.00	1.00
<21 teeth	288 (27%)	**1.56 (1.21, 2.01)**	1.15 (0.85, 1.56)	199 (19%)	**1.53 (1.13, 2.06)**	1.22 (0.87, 1.73)	183 (18%)	**1.74 (1.26, 2.40)**	1.46 (0.98, 2.17)
Subjective									
Self-rated oral health									
Good or excellent	290 (22%)	1.00	1.00	217 (17%)	1.00	1.00	182 (14%)	1.00	1.00
Fair or poor	241 (34%)	**1.78 (1.45, 2.18)**	**1.44 (1.12, 1.85)**	170 (24%)	**1.53 (1.21, 1.92)**	1.23 (0.94, 1.60)	171 (24%)	**1.90 (1.50, 2.41)**	**1.66 (1.24, 2.22)**
Dry mouth symptoms									
0	135 (18%)	1.00	1.00	92 (12%)	1.00	1.00	77 (10%)	1.00	1.00
1–2	153 (23%)	**1.40 (1.08, 1.82)**	1.26 (0.92, 1.72)	108 (16%)	**1.43 (1.06, 1.94)**	1.24 (0.88, 1.75)	109 (17%)	**1.80 (1.31, 2.48)**	**1.67 (1.15, 2.47)**
≥3	245 (41%)	**3.05 (2.37, 3.92)**	**2.89 (2.14, 3.91)**	188 (31%)	**3.12 (2.35, 4.13)**	**2.68 (1.94, 3.69)**	164 (27%)	**3.11 (2.30, 4.21)**	**2.90 (2.01, 4.18)**
Difficulty eating									
No	373 (27%)	1.00	1.00	261 (19%)	1.00	1.00	232 (17%)	1.00	1.00
Yes	51 (40%)	**1.80 (1.23, 2.63)**	1.28 (0.81, 2.04)	44 (34%)	**2.22 (1.50, 3.30)**	**1.67 (1.05, 2.65)**	47 (37%)	**2.90 (1.95, 4.32)**	**2.39 (1.46, 3.89)**
Number of cumulative oral health problems†									
0	43 (13%)	1.00	1.00	24 (7%)	1.00	1.00	20 (6%)	1.00	1.00
1	232 (23%)	**1.82 (1.27, 2.59)**	1.27 (0.83, 1.93)	161 (16%)	**2.20 (1.40, 3.45)**	1.64 (0.98, 2.72)	146 (14%)	**2.02 (1.17, 3.48)**	1.77 (0.98, 3.19)
2	191 (36%)	**3.44 (2.38, 4.99)**	**2.25 (1.45, 3.48)**	146 (27%)	**4.36 (2.75, 6.91)**	**3.29 (1.96, 5.52)**	128 (24%)	**3.84 (2.23, 6.62)**	**3.01 (1.65, 5.49)**
≥3	98 (44%)	**4.62 (3.04, 7.03)**	**2.83 (1.71, 4.67)**	81 (36%)	**6.36 (3.85, 10.51)**	**4.19 (2.36, 7.43)**	82 (36%)	**7.67 (4.34,13.57)**	**5.94 (3.10, 11.37)**
Dental service use									
Regular check-up	286 (21%)	1.00	1.00	214 (16%)	1.00	1.00	174 (13%)	1.00	1.00
Occasional check-up	48 (32%)	**1.62 (1.11, 2.35)**	1.33 (0.84, 2.11)	42 (27%)	**1.85 (1.25, 2.73)**	1.42 (0.88, 2.29)	42 (28%)	**2.35 (1.57, 3.50)**	**2.01 (1.21, 3.34)**
Only when having trouble	88 (38%)	**2.07 (1.53, 2.79)**	**1.51 (1.04, 2.19)**	62 (27%)	**1.69 (1.21, 2.36)**	1.29 (0.87, 1.91)	68 (29%)	**2.44 (1.75, 3.40)**	**1.93 (1.27, 2.91)**
Never go to the dentist	116 (38%)	**2.06 (1.57, 2.69)**	1.25 (0.88, 1.76)	74 (25%)	**1.50 (1.10, 2.04)**	1.05 (0.72, 1.53)	76 (25%)	**1.95 (1.43, 2.67)**	1.33 (0.90, 1.98)

Bold indicates $P < .05$.

*Adjusted for age, social class, smoking, physical activity, history of CVD, and diabetes.

†≥3 dry mouth symptoms, <21 remaining teeth, difficulty eating because of mouth or teeth or dentures problems, sensitivity to hot or cold or sweets.

Table 3
ORs (95% CI) for The Association of Oral Health Markers With Grip Strength, Gait, and Chair Stand Speed in 1722 Older Men Age 71–92 Years in the BRHS

Oral Health Markers	Weakest Grip Strength (n = 347; 21%)			Slowest Gait Speed (n = 337; 21%)			Slowest Chair Stand Speed (n = 390; 24%)		
	n (%)	Age-Adjusted	Fully- Adjusted*	n (%)	Age-Adjusted	Fully- Adjusted*	n (%)	Age- Adjusted	Fully Adjusted*
Objective		OR (95% CI)	OR (95% CI)		OR (95% CI)	OR (95% CI)		OR (95% CI)	OR (95% CI)
Tooth loss									
≥21teeth	111 (19%)	1.00	1.00	91 (16%)	1.00	1.00	112 (20%)	1.00	1.00
15–20 teeth	59 (18%)	0.87 (0.61, 1.23)	0.89 (0.61, 1.29)	49 (15%)	**0.89 (0.60, 1.30)**	**0.63 (0.41, 0.98)**	62 (20%)	**0.94 (0.66, 1.34)**	0.83 (0.56, 1.22)
8–14 teeth	58 (23%)	1.13 (0.78, 1.63)	1.11 (0.74, 1.66)	60 (25%)	**1.51 (1.03, 2.20)**	1.00 (0.64, 1.56)	71 (29%)	**1.49 (1.05, 2.12)**	1.22 (0.82, 1.83)
1–7 teeth	26 (22%)	0.98 (0.60, 1.60)	1.00 (0.59, 1.72)	29 (26%)	**1.44 (0.88, 2.36)**	0.93 (0.53, 1.62)	34 (31%)	**1.48 (0.93, 2.36)**	1.23 (0.73, 2.03)
0 teeth	79 (24%)	1.10 (0.78, 1.54)	1.20 (0.82, 1.76)	96 (31%)	**1.82 (1.29, 2.57)**	1.16 (0.77, 1.74)	99 (32%)	**1.53 (1.11, 2.12)**	1.19 (0.81, 1.75)
Edentulism									
≥1 teeth	254 (20%)	1.00	1.00	229 (18%)	1.00	1.00	279 (23%)	1.00	1.00
0 teeth	79 (24%)	1.11 (0.83, 1.49)	0.83 (0.60, 1.16)	96 (31%)	**1.64 (1.22, 2.19)**	1.30 (0.92, 1.84)	99 (32%)	**1.36 (1.02, 1.80)**	1.15 (0.83, 1.61)
Tooth loss									
≥21teeth	111 (19%)	1.00	1.00	91 (16%)	1.00	1.00	112 (20%)	1.00	1.00
<21 teeth	222 (22%)	1.01 (0.78, 1.32)	0.97 (0.72, 1.29)	234 (24%)	**1.38 (1.04, 1.81)**	0.90 (0.65, 1.24)	266 (27%)	**1.31 (1.02, 1.70)**	0.94 (0.70, 1.26)
Subjective									
Self-rated oral health									
Good or excellent	224 (21%)	1.00	1.00	185 (18%)	1.00	1.00	226 (22%)	1.00	1.00
Fair or poor	105 (19%)	0.83 (0.64, 1.08)	0.83 (0.62, 1.10)	128 (25%)	**1.44 (1.10, 1.87)**	1.00 (0.73, 1.35)	141 (27%)	1.28 (0.99, 1.64)	1.01 (0.76, 1.35)
Dry mouth symptoms									
0	107 (18%)	1.00	1.00	91 (15%)	1.00	1.00	123 (21%)	1.00	1.00
1–2	118 (22%)	1.34 (1.00, 1.80)	1.25 (0.91, 1.72)	106 (21%)	**1.51 (1.10, 2.08)**	1.34 (0.93, 1.91)	116 (23%)	1.14 (0.85, 1.53)	0.96 (0.70, 1.33)
≥3	102 (22%)	1.20 (0.88, 1.63)	1.15 (0.83, 1.61)	120 (28%)	**1.98 (1.44, 2.72)**	**1.75 (1.22, 2.50)**	131 (30%)	**1.56 (1.17, 2.09)**	1.33 (0.96, 1.84)
Difficulty eating									
No	225 (20%)	1.00	1.00	216 (20%)	1.00	1.00	266 (25%)	1.00	1.00
Yes	24 (23%)	1.11 (0.68, 1.81)	1.22 (0.72, 2.06)	34 (34%)	**1.90 (1.20, 3.01)**	1.49 (0.88, 2.50)	36 (36%)	**1.58 (1.02, 2.45)**	1.23 (0.75, 2.04)
Number of cumulative oral health problems†									
0	63 (19%)	1.00	1.00	51 (16%)	1.00	1.00	53 (16%)	1.00	1.00
1	169 (22%)	1.09 (0.79, 1.52)	1.16 (0.81, 1.66)	146 (19%)	1.18 (0.83, 1.68)	0.84 (0.56, 1.26)	184 (24%)	**1.56 (1.11, 2.20)**	1.23 (0.84, 1.81)
2	81 (21%)	0.98 (0.67, 1.42)	1.03 (0.68, 1.56)	85 (23%)	1.39 (0.94, 2.07)	0.92 (0.58, 1.44)	101 (27%)	**1.75 (1.20, 2.55)**	1.38 (0.90, 2.10)
≥3	34 (20%)	0.93 (0.58, 1.49)	1.03 (0.61, 1.74)	55 (35%)	**2.49 (1.57, 3.93)**	1.52 (0.90, 2.57)	52 (33%)	**2.24 (1.43, 3.52)**	1.58 (0.95, 2.63)
Dental service use									
Regular check-up	228 (20%)	1.00	1.00	185 (17%)	1.00	1.00	226 (21%)	1.00	1.00
Occasional check-up	19 (17%)	0.73 (0.43, 1.23)	0.83 (0.48, 1.46)	25 (24%)	1.40 (0.86, 2.30)	1.06 (0.60, 1.88)	28 (27%)	1.29 (0.81, 2.07)	1.30 (0.77, 2.19)
Only when having trouble	35 (22%)	0.93 (0.61, 1.39)	0.87 (0.56, 1.37)	50 (33%)	**2.04 (1.39, 3.01)**	**1.69 (1.08, 2.62)**	45 (29%)	1.36 (0.92, 2.00)	1.07 (0.69, 1.65)
Never go to the dentist	52 (24%)	1.08 (0.75, 1.53)	1.10 (0.74, 1.64)	61 (29%)	**1.67 (1.17, 2.38)**	0.98 (0.65, 1.50)	72 (35%)	**1.74 (1.25, 2.42)**	1.43 (0.97, 2.11)

Bold indicates $P < .05$.

*Adjusted for age, social class, smoking, physical activity, history of CVD, and diabetes.

†≥3 dry mouth symptoms, <21 remaining teeth, difficulty eating because of mouth or teeth or dentures problems, sensitivity to hot or cold or sweets.

Table 4
ORs (95% CI) for The Association of Oral Health Markers With Mobility Limitations and ADL Problems in 3075 Older Men and Women Age 71–80 Years in the HABC Study

Oral Health Markers	Mobility Limitations (n = 882; 29%)			ADL Problems (n = 467; 17%)		
	n (%)	Age-Adjusted	Fully- Adjusted*	n (%)	Age-Adjusted	Fully- Adjusted*
Objective		OR (95% CI)	OR (95% CI)		OR (95% CI)	OR (95% CI)
Tooth loss						
≥21teeth	212 (23%)	1.00	1.00	138 (15%)	1.00	1.00
15–20 teeth	90 (25%)	1.16 (0.87, 1.54)	0.95 (0.70, 1.29)	61 (17%)	1.19 (0.85, 1.65)	1.15 (0.82, 1.62)
8–14 teeth	96 (34%)	**1.78 (1.33, 2.37)**	**1.44 (1.06, 1.98)**	68 (25%)	**1.86 (1.34, 2.58)**	**1.74 (1.23, 2.47)**
1–7 teeth	55 (30%)	**1.49 (1.05, 2.11)**	1.12 (0.77, 1.65)	33 (18%)	1.30 (0.86, 1.98)	1.24 (0.79, 1.93)
0 teeth	70 (34%)	**1.72 (1.24, 2.38)**	1.02 (0.70, 1.49)	30 (15%)	1.01 (0.66, 1.55)	0.91 (0.57, 1.44)
Edentulism						
≥1 teeth	453 (26%)	1.00	1.00	300 (17%)	1.00	1.00
0 teeth	70 (34%)	**1.46 (1.07, 1.98)**	0.94 (0.66, 1.33)	30 (15%)	0.85 (0.57, 1.28)	0.74 (0.48, 1.15)
Tooth loss						
≥21teeth	212 (23%)	1.00	1.00	138 (15%)	1.00	1.00
<21 teeth	311 (30%)	**1.49 (1.21, 1.82)**	1.12 (0.89, 1.41)	192 (19%)	**1.34 (1.06, 1.71)**	1.28 (0.98, 1.66)
Subjective						
Self-rated oral health						
Good or excellent	435 (23%)	1.00	1.00	278 (15%)	1.00	1.00
Fair or poor	300 (36%)	**1.31 (1.21, 1.41)**	**1.19 (1.10, 1.30)**	185 (22%)	**1.30 (1.18, 1.43)**	**1.27 (1.15, 1.41)**
Dry mouth symptoms						
No	689 (26%)	1.00	1.00	428 (16%)	1.00	1.00
Yes	52 (49%)	**2.66 (1.80, 3.92)**	**2.26 (1.50, 3.39)**	35 (33%)	**2.49 (1.64, 3.78)**	**2.23 (1.46, 3.41)**
Difficulty eating						
No	546 (25%)	1.00	1.00	328 (15%)	1.00	1.00
Yes	196 (37%)	**1.76 (1.44, 2.15)**	**1.51 (1.22, 1.86)**	138 (26%)	**1.99 (1.58, 2.49)**	**1.90 (1.50, 2.40)**
Number of cumulative oral health problems†						
0	173 (22%)	1.00	1.00	108 (14%)	1.00	1.00
1	355 (26%)	1.23 (1.00, 1.52)	0.98 (0.78, 1.22)	202 (15%)	1.08 (0.84, 1.39)	1.07 (0.82, 1.39)
2	120 (31%)	**1.53 (1.16, 2.01)**	1.14 (0.85, 1.53)	86 (22%)	**1.70 (1.24, 2.33)**	**1.61 (1.16, 2.24)**
≥3	107 (48%)	**3.28 (2.40, 4.49)**	**2.19 (1.56, 3.07)**	71 (32%)	**2.88 (2.03, 4.08)**	**2.63 (1.81, 3.81)**
Dental service use						
2 times or more per year	276 (22%)	1.00	1.00	205 (16%)	1.00	1.00
Once per year	119 (27%)	**1.33 (1.04, 1.71)**	1.11 (0.85, 1.45)	62 (14%)	0.85 (0.62, 1.15)	0.79 (0.57, 1.08)
Less than once per year	331 (33%)	**1.78 (1.48, 2.15)**	**1.30 (1.04, 1.62)**	188 (19%)	1.20 (0.96, 1.49)	1.08 (0.84, 1.40)

Bold indicates $P < .05$.
*Adjusted for age, sex, race, education, smoking, physical activity, history of CVD, and diabetes.
†Dry mouth when eating, <21 remaining teeth, any difficulty eating or chewing, limit of food because of gum problems.

strength in the fully adjusted model. Associations of dry mouth with disability and physical function did not materially change after adjusting for medications use (results not presented).

Adjustment for self-rated general health attenuated some of the associations reported above, including tooth loss, self-rated oral health and dental service with disability measures, and dry mouth and dental service with slow gait speed in the BRHS, and self-rated oral health and dental service with mobility limitations and self-rated oral health with slow gait speed in the HABC Study (results not presented).

Discussion

Our study comprising 2 samples of community-dwelling older people from the UK and US found that tooth loss, dry mouth, poor self-rated oral health, and cumulative oral health problems were associated with mobility limitations, ADL problems, and IADL problems. Dry mouth and poor self-rated oral health were also associated with poor physical function. This study provides new evidence on the associations of objective and subjective oral health markers with disability and physical function in older age.

After adjustment for self-rated general health, the associations of partial tooth loss, edentulism, and self-rated oral health with disability (mobility limitations, ADL, and IADL) were abolished in the BRHS, showing that these associations could be influenced by poor underlying health status. Nevertheless, associations between tooth loss and disability remained significant in the HABC Study, in accordance with previous studies.[8,9,14–17] Our findings support the hypothesis that poor oral health and disability coexist in older age. However our cross-sectional findings are unable to demonstrate if poor oral health leads to the development of disability and whether these associations are causal. Furthermore, we found that dry mouth was associated with a greater risk of disability in both studies, even after adjustment for medications causing xerostomia. Dry mouth is highly prevalent in older people and is linked to comorbidities because of the number of medications commonly prescribed to older people.[24] The positive association of dry mouth with disability adds to the existing literature and suggests that dry mouth is an important oral health condition that may be independently linked to the physical condition of individuals. These results also highlight that subjective measures such as dry mouth and self-rated oral health are important markers of poor oral health in older age.

In the BRHS, periodontal pocket depth, a marker of acute periodontal disease, was associated with weak grip strength. A previous study did not report any association between periodontal disease and grip strength cross-sectionally, but found that periodontal disease led to a decrease in grip strength over time.[18] Although tooth loss has been linked to gait stability and speed,[11,34] in our study tooth loss was not associated with physical function, either grip strength or gait or chair-stand speed. However, subjective oral health markers, such as dry mouth, were associated with poor physical function in both our study populations. A previous study reported that dry mouth was associated with poor oral health-related quality of life, but did not examine the relations with physical function.[35] However, our previous study on frailty, which is closely linked to physical function since grip strength and gait speed are 2 components of frailty, reported an association between dry mouth and frailty, thus, emphasizing the importance of dry mouth in the functional capacity of older people.[27] Moreover, the observed association of poor dental service use and

Table 5
ORs (95%CI) for The Association of Oral Health Markers With Grip Strength and Gait Speed in 3075 Older Men and Women Age 71–80 Years in the HABC Study

Oral Health Markers	Weakest Grip Strength (n = 469; 20%)			Slowest Gait Speed (n = 375; 20%)		
	N (%)	Age-Adjusted	Fully- Adjusted*	*N* (%)	Age- Adjusted	Fully- Adjusted*
Objective		OR (95% CI)	OR (95% CI)		OR (95% CI)	OR (95% CI)
Tooth loss						
≥21teeth	159 (20%)	1.00	1.00	49 (7%)	1.00	1.00
15–20 teeth	59 (19%)	0.94 (0.68, 1.32)	0.85 (0.59, 1.24)	20 (8%)	1.44 (0.99, 2.09)	1.08 (0.73, 1.62)
8–14 teeth	36 (16%)	0.75 (0.50, 1.11)	0.66 (0.42, 1.03)	19 (12%)	1.52 (0.99, 2.32)	1.08 (0.68, 1.71)
1–7 teeth	24 (15%)	0.76 (0.48, 1.22)	0.71 (0.42, 1.21)	11 (10%)	1.55 (0.94, 2.56)	1.08 (0.63, 1.85)
0 teeth	30 (18%)	0.90 (0.58, 1.38)	0.72 (0.43, 1.21)	15 (11%)	**2.02 (1.30, 3.12)**	1.15 (0.70, 1.89)
Edentulism						
≥1 teeth	278 (18%)	1.00	1.00	99 (8%)	1.00	1.00
0 teeth	30 (18%)	0.98 (0.64, 1.49)	0.86 (0.53, 1.40)	15 (11%)	**1.63 (1.08, 2.47)**	1.06 (0.67, 1.68)
Tooth loss						
≥21teeth	159 (20%)	1.00	1.00	49 (7%)	1.00	1.00
<21 teeth	147 (17%)	0.85 (0.66, 1.09)	0.76 (0.56, 1.02)	65 (10%)	**1.59 (1.20, 2.10)**	1.09 (0.80, 1.50)
Subjective						
Self-rated oral health						
Good or excellent	317 (19%)	1.00	1.00	101 (7%)	1.00	1.00
Fair or poor	148 (21%)	1.07 (0.98, 1.17)	1.06 (0.96, 1.18)	74 (15%)	**1.31 (1.18, 1.46)**	**1.16 (1.03, 1.30)**
Dry mouth symptoms						
No	430 (19%)	1.00	1.00	167 (9%)	1.00	1.00
Yes	33 (37%)	**2.58 (1.65, 4.03)**	**2.43 (1.47, 4.01)**	8 (14%)	1.78 (0.98, 3.25)	1.54 (0.82, 2.89)
Difficulty eating						
No	389 (20%)	1.00	1.00	129 (8%)	1.00	1.00
Yes	79 (18%)	0.85 (0.65, 1.11)	0.84 (0.62, 1.14)	47 (14%)	**1.57 (1.19, 2.08)**	1.29 (0.96, 1.75)
Number of cumulative oral health problems†						
0	130 (19%)	1.00	1.00	35 (6%)	1.00	1.00
1	235 (20%)	1.06 (0.84, 1.35)	1.01 (0.77, 1.32)	91 (10%)	**1.86 (1.40, 2.48)**	**1.40 (1.03, 1.91)**
2	63 (19%)	1.00 (0.72, 1.40)	0.92 (0.63, 1.34)	28 (11%)	**1.97 (1.35, 2.87)**	1.31 (0.88, 1.97)
≥3	41 (22%)	1.23 (0.82, 1.83)	1.06 (0.67, 1.67)	22 (18%)	**2.35 (1.47, 3.76)**	1.40 (0.84, 2.33)
Dental service use						
2 times or more per year	226 (21%)	1.00	1.00	62 (7%)	1.00	1.00
Once per year	68 (18%)	0.87 (0.65, 1.18)	0.88 (0.63, 1.24)	31 (11%)	**1.79 (1.27, 2.50)**	**1.56 (1.09, 2.23)**
Less than once per year	171 (20%)	1.00 (0.80, 1.25)	0.99 (0.74, 1.32)	80 (13%)	**2.35 (1.81, 3.04)**	**1.64 (1.21, 2.23)**

Bold indicates $P < .05$.
*Adjusted for age, sex, race, education, smoking, physical activity, history of CVD, and diabetes.
†Dry mouth when eating, <21 remaining teeth, any difficulty eating or chewing, limit of food because of gum problems.

physical function shows that limited access to oral health services may influence the physical condition of older people. Most of these associations with physical function remained significant and were independent of pre-existing CVD, diabetes, and poor self-rated general health.

Possible pathways underlying the associations between tooth loss and disability could be inflammation and poor nutrition. Tooth loss is linked to previous periodontal disease.[36] Periodontal disease is characterized by chronic oral inflammation, which may be associated with increased levels of systemic inflammation (ie, C-reactive protein, IL-6)[37] and, therefore, could contribute to disability.[19] Furthermore, individuals with poor oral health, particularly tooth loss, tend to have poor nutritional status as a result of decreased consumption of specific food groups and impaired mastication,[38] which can in turn affect muscle strength and consequently contribute to disability (ADL, IADL, and mobility limitations) and decreased physical function.[39,40] Likewise, dry mouth in older people often leads to ulceration and inflammation of oral mucosa, which can create difficulties in eating and swallowing; this can also significantly impact dietary intake and poor nutritional status, and increase the risk of disability.[39,41]

In this study, the associations of a range of both objective and subjective markers of oral health with disability and physical function were examined. Few studies have examined subjective oral health measures such as self-rated oral health and dry mouth; studies so far have mostly focused on tooth loss and periodontal disease. Furthermore, we created a composite measure of oral health problems as an indicator of the burden of oral health problems in older people. Also, the lack of correlation and the observed differences in the associations of objective and subjective measures indicate the importance of utilizing both of these measures separately because we cannot use objective measures as indicators of subjective oral problems or vice versa. This study has some limitations. Our findings are based on cross-sectional analyses, and the results cannot establish a causal relationship between oral health and disability or poor physical function. Nevertheless, the findings are supported by longitudinal analyses in the BRHS, where tooth loss and dry mouth were associated with higher risks of developing frailty.[27] In addition, both cohorts may not be representative of the general populations of the UK and US. Furthermore, although the studies were comparable in terms of having community-dwelling older people, there were differences in the populations (BRHS comprised men only) and in assessments of oral health measures (ie, periodontal disease and dry mouth). Nevertheless, we observed similar associations between poor oral health and disability in the 2 studies. Moreover, while we were able to adjust for a range of covariates in both studies, the possibility of residual confounding remains because of possible confounders which were not available in the studies or due to measurement error and underreporting of confounders. Furthermore, poor oral health may be a proxy of poor socioeconomic or physical status throughout the life-course. It is also likely in both studies that individuals who participated were healthier with better oral health and physical function status than those who did not attend.[27] Therefore, the potential for under-adjustment remains in our findings.

Conclusions and Implications

We found that oral health problems, particularly tooth loss, poor self-rated oral health, and dry mouth, were associated with disability and impaired physical function in older populations. These findings merit further research in longitudinal studies, examining the possible

mediating roles of nutrition and inflammation to establish the influence of oral health markers on development of disability. Nonetheless, our findings suggest that healthcare professionals responsible for the care of older people should take into consideration the oral health status of older people, including the individual's perception of his or her oral problems. Moreover, screening tools of dental health[42] could be useful in identifying and preventing oral health problems and maintaining a good quality of life in older people.

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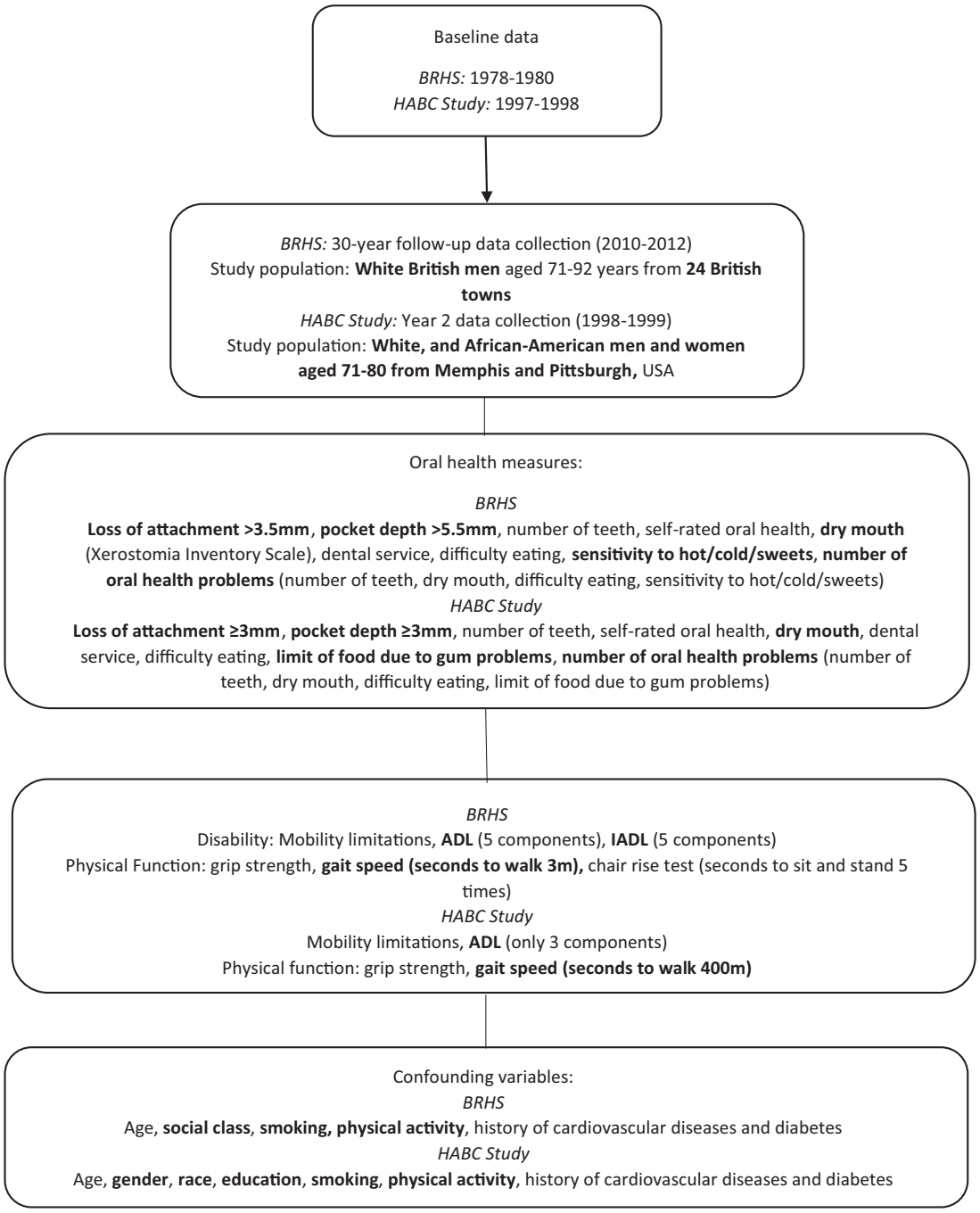
Appendix



Supplementary Fig. 1. Flowchart of the study characteristics of the BRHS and the HABC. Bold indicates difference between the 2 studies.